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LIST OF RUSSIAN PAPERS [redacted]

1. Bratsk Hydro-Electric Power Plant.
2. Krasnoyarsk Hydro-Electric Power Plant.
3. The Dniepr Cascade of Hydro-Electric Power Plants.
4. Kremenchug Hydro-Electric Power Plant.
5. The All-Union Research Institute of Electrical Energy.
6. Research Institute for Direct Current.
7. Telemechanized Dispatcher Point of an Electric Power System.
8. A System for the Correction of Active Power for the Automatic Regulation of the Frequency and Load of Groups of Multi-Unit Power Plants.
9. Electrical RPM Relay.
10. Development of Electric Power Transmission Lines, in the USSR.
11. Air Circuit Breaker Type BB-500.
12. Single Phase Power Auto-Transformer (Step-Up).
13. Current Transformer.
14. Voltage Transformer.
15. Three Phase, Three Winding Transformer.
16. Synchronous Machines Type TCD-DC.
17. CW Motors Type ATD.
18. Development of Electrical Power in the U.S.S.R. in 1959 - 1965 by A. M. Nekrasov

[redacted]

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1. BRATSK HYDRO-ELECTRIC POWER PLANT

Descriptive bulletin. This power plant is under construction. It is located on the Angara River in Siberia. The dam is scheduled for completion in 1959. It is scheduled to go on line in 1961. Each turbine will have a rating of 225 MW. Total capacity will be 3600 MW with a possibility to increase to 4500 MW.

The Bratsk plant is the fourth on the Angara River. The first at Irkutsk went into service in 1956. A total of six power plants with a total capacity of 10 million KW will be built on the Angara River. The illustrations show the Padunsk Gorge before construction was started.

2. KRASNOYARSK HYDRO-ELECTRIC POWER PLANT

Descriptive bulletin. This power plant is under construction. It is located on the Yenisey River in Siberia. Total installed rating will be 4200 MW and it will be the largest and most efficient hydro-electric plant in Russia. The power plant will be located near the city of Krasnoyarsk and will be connected by a 500 KV transmission line with the Bratsk power plant and with the Kooznetsk region.

The topography of the proposed sight is characterized by a narrow gorge with steep rocky shores. The climate of this region is strictly continental -- average yearly temperature 0.4°C (32°F) max. temp. in July 37°C (98.6F) and a minimum in January - 54°C (-65°F). Average number of days without frost per year 112. Thermal joints will be provided longitudinally with vertical gaps. This permits to reduce the reaction at the base and a reduction of the amount of concrete required.

The power plant will be 437 M. long (1433 ft.) and will house 14 radial-axial turbines with a 6.6 M. (21.65 ft.) dia. of the blade wheel. The inlet pipes are made from metal and are 8.5 M. (27.887 ft.) in dia. They are provided with grids and flat closures hydraulically operated. Each umbrella type water wheel generator is rated 300 MW at 100 rpm. The transmission voltage is 220 and 500 KV. The starting date of the first generators is scheduled for 1965. The design of the Krasnoyarsk plant is made by the Leningrad division of the Hydro-Energy Project.

3. THE DNIEPR CASCADE OF HYDRO-ELECTRIC POWER PLANTS

The Dniepr is the third largest river in Europe (after Volga and Danube). The Dniepr starts in northern Russia and flows from north to south. It is 2285 KM (1420 miles) long. It discharges into the Black Sea at Hersones. Most of hydro-electric potential power of the Dniepr is below Kiev (about 90%). See Map Fig. 1. The construction of dams in the lower Dniepr region provides means of irrigation which is badly needed in that rather dry area. The following six hydro-electric plants are planned on the lower Dniepr: The Kiev, Kanev, Kremenchug, Dneprodzerzinsk, Dniepr-Lenin and Kahovka. See Fig. 12. The construction of these dams will provide irrigation for 3.5 million hectars (8.65 million acres)

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and will make the lower Dniepr navigable from Kiev to the Black Sea. In 1932 [redacted] the first power plant (the Dniepr-Lenin) was completed. The flooded area covered the Dniepr Rapids and the construction of locks made the river navigable all the way down to the sea.

Next the Kahovka dam was built. In 1954 the construction of the Kremenchug Dam was started and also the Dnieprodzerzinsk Dam. Above power plants will be connected by high voltage transmission lines with the Donets Region and the Volga power plants and thus become part of the combined power system of European Russia.

The potential capacity of the Dniepr River is estimated at 1.65 million KW and the corresponding electrical output would be 14.5 billion KW HOUR per year. Below is a breakdown of the output for each power plant:

1. Kiev - no rating specified.
2. Kanev - 250,000 KW. Average yearly output: 805 million KW hours.
3. Kremenchug - 625,000 KW - 1506 million KW hours per year.
4. Dnieprodzerzinsk - 350,000 KW - 1,250 million KW hours per year.
5. Dniepr-Lenin - 650,000 KW - 3,640 million KW hours per year.
6. Kachovka - 312,000 KW - 1435 million KW hours per year.

4. THE KREMENCHUG HYDRO-ELECTRIC POWER PLANT

A detail description of the power plant No. 3 listed above. An estimated date 1961 is given for the filling of the reservoir.

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5. THE ALL UNION RESEARCH INSTITUTE OF ELECTRICAL ENERGY

The Central Electrical Research Laboratory, which was originally (1944) organized as a part of the ministry of power plants, was reorganized early in 1958 as the All Union Research Institute of Electrical Energy.

The Research Institute is concerned with the efficient operation of power systems, transmission lines and the unification of electrical systems and coordination of the electrical equipment in the industry with new methods of power generation. [redacted] [redacted]

6. RESEARCH INSTITUTE FOR DIRECT CURRENT

INTRODUCTION

This Institute is concerned with the development of D.C. transmission lines. A.C. transmission lines with voltages up to 400 KV are also investigated in this Institute.

Unique test installations are located in Leningrad and Moscow, and include the following:

1. D.C. transmission line between Kashira and Moskow 200 KV, 30 MW, 112 KM (70 miles).

2. A 120 MVA test stand for testing high voltage valves. Also a number of equivalent stands and systems for the investigation, testing and development of valves.

3. Electrodynamical model of large combined power systems with power generators simulating the present synchronous machines.

4. High voltage test installations which permit a thorough testing of the equipment for D.C. power transmission up to 1200 KV and A.C. transmission up to 650-700 KV.

5. A number of special installations and models.

In cooperation with the project organizations and the electric manufacturing industry, the Institute develops and designs the non-standard equipment of the first industrial D.C. transmission line between Stalingrad Hydro-Electric Plant and the Donets Region (Donbass), 800 KV, 750 MW, 470 KM (292 miles).

The Institute also carries development work for the establishment of D.C. transmission lines in the power system of the Soviet Union.

The Institute also studies line insulation, internal over-voltage, corona effects, development of axial compensation, stability problems, etc. The results of above investigations are used in the design of A.C. transmission lines with 400 KV and higher.

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D.C. HIGH VOLTAGE POWER TRANSMISSION

EXPERIMENTAL INDUSTRIAL D.C. TRANSMISSION LINE BETWEEN KASHIRA AND MOSKOW

Built in 1951 - Capacity 30,000 KW - rated voltage 200 KV. It consists of a rectifier station at Kashira and an inverter station at Moskow connected by a two cable line 112 KM (69.6 miles) long. See Fig. 1.

The current is converted by means of metal single anode, dismantable mercury valves with different modifications. Basic electrical specifications of the valves: max. current 150 amps, reverse voltage 120-130 KV.

The transmission line consists of two single strand cables which carry D.C. current at 200 KV. The cable has an aluminum current carrying core with a cross section of 150 MM^2, a paper insulation 11-12 mm. thick with a viscous impregnation , a lead shield and a steel shell.

Fig. 2 Kashira - Moskow transmission line. Open-air part of the conversion station.

Fig. 3 Valve (rectifier) hall.

Fig. 4 Valves and auxiliary equipment.

MODELS FOR THE INVESTIGATION OF D.C. TRANSMISSION

Most of these investigations are carried out for the design of the Stalingrad-Donets Region transmission line. It includes:

A model for the investigation of stationary and transient phenomena.

A model of a D.C. transmission system for the investigation of the control equipment, adjustment and protection. See Fig. 5.

A model for the investigation of vibrations and internal overvoltages in D.C. transmission lines. See Fig. 6. Acustic frequency vibrations have been investigated on this model and methods of damping these vibrations.

A model of the conversion system for the investigation of high frequency vibrations (10^5, 10^6 cycles) during the starting of the valves.

D.C. TRANSMISSION LINE STALINGRAD TO DONETS REGION

The main design data are:

Capacity 750 MW.
Rated voltage 800 KV.
Overhead transmission line 470 KM (292 Miles) long.

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HIGH VOLTAGE VALVES (RECTIFIERS)

Development work is carried out by the Institute: manufacturing technology, assembly methods and test methods of high voltage valves. See Fig. 7.

Design of high voltage valves and investigation of physical processes in the valves. Fig. 8, 9, 10, 11 and 12.

HIGH VOLTAGE TECHNOLOGY

HIGH VOLTAGE TEST INSTALLATIONS

VOLTAGE IMPULSE GENERATOR. Fig. 13. Rated voltage 4.3 million volts, shock capacity 16,700 micromicrofarad, stored energy 155 KW. Sec. Efficiency 0.8 for a standard wave of 1.5/40 MICROSEC. The high voltage of this generator and high shock capacity permits the testing of apparatus built for transmission lines with a rated voltage of 650-700 KV, which as a rule have high inlet capacity.

CURRENT IMPULSE GENERATOR. Chargin voltage 100 and 200 KV, shock capacity 80 microfarad at 100 KV, and 20 microfarad at 200 KV. Stored energy 400 KW Sec. Amplitude of discharge current up to 500,000 amps. The generator is set in a pit, below the floor level.

SINGLE PHASE TEST TRANSFORMER for industrial frequency, 50 cycles, Fig. 14. Rated voltage 1 million volt, capacity 1000 KVA. This transformer is energized by a special single phase generator rated at 600 KW which is driven by a wound rotor motor rated 350 KW.

D.C. CURRENT INSTALLATION. Fig. 15. Rated voltage 1.2 million volts. Average value of rectified current permissible for a long period 70 milliamps. Average value of current permissible for a short period (up to 10 sec.) 200 milliamps. This installation is designed on the principle of doubling the voltage. Rectifiers are high voltage kenotrons, which are heated to glow by means of a special transformer. At maximum load the voltage fluctuates about 5-7%.

HIGH FREQUENCY INSTALLATION. (Tesla transformer). Rated voltage 1.5 million volts. Frequency 30 to 150 Kilocycles.

In the large high voltage hall a generator of impulse voltage up to 1 million volts and a capacity of 10,000 micromicrofarad is installed.

Spherical dischargers with 2.5 and 1.5 M. diameter of the spheres. A capacity type voltage divider with 3.5 M. dia. electrodes and a cylindrical air condenser 3.5 M. in dia. for an operating voltage of 600 KV and a capacity about 100 micromicrofarad.

For long range investigations and for the test of lower voltage apparatus a small high voltage hall is available.

A number of special test set-ups is also available, for the testing of condensers, insulators, etc., at high temperatures, high humidity, etc.

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CASCADE OF TEST TRANSFORMERS AND EXPERIMENTAL SECTION OF AN OVERHEAD TRANSMISSION LINE

The cascade consists of three transformers each rated at 750 KV and 750 KVA. It is an outdoor installation Fig. 16. These transformers can be connected in star with a line to line voltage of 1300 KV, or in series with 2250 KV to ground.

For the investigation of corona discharges a 1 KM long experimental section of a transmission line has been built.

MODEL FOR INVESTIGATION OF INTERNAL OVERVOLTAGES IN THREE PHASE NETWORKS FOR HIGH VOLTAGES. Fig. 18.

OPERATION PROBLEMS OF LONG DISTANCE TRANSMISSION LINES AND COMBINED POWER SYSTEMS

Studies are made of static and dynamic stability of combined power systems.

Self-excitation of synchronous machines.
Investigation of compensation methods.

ELECTRODYNAMIC MODEL. (Network analyzer).
Figures 19, 20, 21 and 22.

EXPERIMENTAL - INDUSTRIAL INSTALLATION OF LONGITUDINAL COMPENSATION OF TRANSMISSION LINE REACTANCE

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TRANSLATION

7. TELEMECHANICAL DISPATCHER POINT OF AN ELECTRIC POWER SYSTEM

(SUPERVISORY CONTROL)

The modern electric power systems supply electric and thermal energy to manufacturing plants, construction works, transportation, agriculture, communal buildings and also satisfy the cultural living requirements of the population. [redacted] These power systems consist of electric power plants with a capacity of tens and hundreds of thousands of kilowatts, a large number of transformer substations and high voltage transmission lines which are hundreds and thousands of kilometers long.

A continuous and well-organized supply of electrical energy to the peoples economy is a requirement for a normal economical and cultural life of our socialistic society.

Considering the enormous size of the electric generating industry, the economic operation of individual electric power plants becomes very important and particularly the rational utilization of hydraulic energy and also of local and imported fuel in the entire power system.

Due to above conditions it was necessary to organize a centralized dispatcher control of individual power systems and also a united dispatcher control which covers a large part of the country (Figure 1).

The dispatcher coordinates the operation of different power plants and specifies for each plant the most economical schedule. He can rapidly eliminate an accident or restrict its expansion and thus prevent interruptions in power supply.

Dispatcher points (united, central, district) are broadly supplied with modern technical equipment - telemechanic.

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Different types of modern telemechanic apparatus permits the dispatcher to control the power system with operation precision and they facilitate his work. The dispatcher point and all stations and substations are connected by telephone. The telemechanical equipment permits the dispatcher to centralize the control, the complex method of generating and distribution of electrical power and to carry it out in the most efficient way considering the over-all requirement of the peoples economy.

The introduction of telemechanics is followed by the equipment of stations and substations with local automatic equipment, which permits a reduction of the operating personnel, and at a number of hydroelectric stations and substations, it is possible to completely eliminate the operating staff.

In the Soviet Union the planned telemechanization of power systems was started after the war.

Industrial manufacturing of standard telemechanical equipment began to develop only during the last five to ten years. The telemechanical equipment which was developed for electrical power systems has been widely used in other branches of our national economy.

At the present time over thirty-two power systems which include about 70 per cent of the entire power output are equipped with telemechanized dispatcher points. Over three hundred network substations operating at 220 KV are equipped with telemechanics and operate without permanent personnel at the panel. Fifty-one hydroelectric power plants, which constitute about 46 per cent of all hydroelectric plants, are telemechanized and are controlled from central dispatch points. In the largest power systems district dispatch points are organized. These points are equipped with a great variety of telemechanical equipment.

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One of the largest in the world, the hydroelectric station at Kuibishev is connected by telemechanical equipment with the United dispatch system at Moscow, i.e. a distance of one thousand kilometers.

In a number of large cities of this country, telemechanized dispatcher points are being built for the city distribution (cable) networks. This will help to improve the supply of power to the cities without interruption.

The distances between the dispatcher points and the controlled equipment varies from tens to many hundreds of kilometers and in the near future increase to several thousand kilometers.

Telemechanics provides the transmission over such distances of practically unlimited number of signals, commands or measurements over one connecting channel. This is obtained either through communication lines or through the rapidly increasing use of high frequency connection through the high voltage transmission lines. (Figure 2)

According to the functions performed, telemechanics is subdivided into:

(a) Telemetering, i.e. transmission of measured values (parameters) which characterize the electrical, thermal and other conditions of operation of the controlled stations, substations and networks.

(b) Telesignaling, i.e. transmission of signals regarding the position of switching equipment, which is either automatically operated or operated by remote control, and also signals about the operation of the generators and other equipment which changes from time to time.

(c) Telecontrol, i.e. transmission of commands and orders of the dispatcher which operate the executive mechanisms at the controlled point; besides that, telecontrol is used for the transmission of a command requesting telemetering.

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Telemetering is used for measurements of active and reactive capacity of the generators, and of total capacity of power plants of the entire power system, for the control of the loads of transformers, the flow of energy in transmission lines, the voltage at different points in the high voltage network, and the frequency in the system.

Besides that, on hydroelectric power plants measurements of the water level are made in water reservoirs and in steam power plants measurements of the pressure and consumption of steam.

Telesignaling is used for the continuous control from the dispatch point of power circuit breakers, the operation of protection relays on transmission lines and power lines and also of local automatic equipment. Telesignaling permits the dispatcher to check the results of the orders and commands which he has sent out.

Telecontrol is used by the dispatcher for starting and shutoff of the high voltage generators, and closing and opening of switchgear. Fast loading and unloading of the generators of one power plant depends on the changing conditions on another one or anywhere in the network.

Besides that, there are telemechanic methods (they include telemetering) which are applied also for purposes of automatic regulation of frequency and active power outputs of power systems. In this case, by means of telemechanic methods, a tie is provided between automatic control equipment which is located in different points of the power system (for example: the dispatcher point and an electric power plant). As a result of that more efficient utilization of the power of plants is obtained.

On the exhibition stand is observed telemechanical equipment which is manufactured by the plant "Electropult" (Leningrad).

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Dispatcher Panel. The most important element of the telemechanized dispatcher point is the panel with a so-called mneumonic (mimic bus) diagram of the power system. On this diagram, by means of symbols, are shown generators, transformers, circuit breakers, disconnectors, bus bars, transmission lines, etc. Sections of the mimic bus diagram which have different voltages are painted in different colors.

The purpose of the mimic bus diagram is to reproduce without the participation of the dispatcher all changes which occur in the power system. Such automatic recording facilitates the work of the dispatcher and guarantees the correct and fast recording of the incoming signals.

For this purpose the symbols of the mimic bus diagram are equipped with bulbs which are controlled by telemechanical signals through the arrangement of telesignaling. The arrival of such signals to the dispatcher point is accompanied by a siren which attracts the attention of the dispatcher and by flashing bulbs on the corresponding symbol. The dispatcher acknowledges manually the new signal to confirm the received information. In this case, the symbol of the circuit breaker goes out and the symbol of the power unit either changes to uniform light (the power unit is working) or goes off.

On the exhibition stand is shown an example of a dispatcher panel with a mimic bus diagram of one power plant.

Dispatcher Console. A dispatcher console is a working desk of the dispatcher. Sitting in front of the console, the dispatcher can observe the entire mimic bus diagram. He can observe the equipment of the telemetering and execute all necessary operations of telecontrol. For that purpose on the console are mounted special switches, buttons, and bulbs.

Some telemeasurements are recorded by means of automatic equipment on paper strips. One equipment, the summarizing electrical recorder of the power

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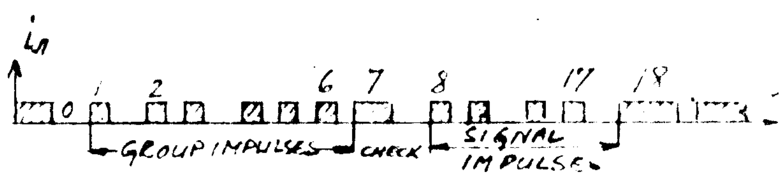

FIG. 4. DIAGRAM OF IMPULSE CODE FOR A TELECONTROL-TELESIGNAL ARRANGEMEN[illegible]

TYPE UTB-55.

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of the entire system, is particularly visible at the dispatcher point (Figure 3).

Arrangement of telecontrol and telesignalization of the Type UTB-55 is designed on time distribution principle.

The transmission of the signal or order consists of the transmission through the channel of a series of consecutive impulses of electrical current which are divided by intervals. The number of the signal (point) is determined by the number of the impulses in the series. The position of the signal (connected or disconnected) is determined by the elongation of the corresponding interval. The number of signals in a series is seventeen.

The receipt of more than two orders shows that the equipment is not properly operating. The transmission of signals can be also controlled. In the arrangement of the telecontrol telesignaling of the UTB-55 type, higher reliability is assured in the transmission of operations of telecontrol telesignaling (Figure 4).

The received series of impulses is decoded and gives a definite execution impulse; at the dispatcher point it connects a signal lamp and at the power plant it disconnects a circuit breaker. The normal arrangement is at standstill and is activated automatically when the object (point) is reswitched.

The arrangement of the UTB-55 is a complicated multi-function system which is designed basically on the basis of an electromagnetic relay of the telephone type and of telephone stepping switches. The feeder voltage is 60 volt d-c.

The UTB-55 arrangement is designed for eighty signals of telesignals, thirty-six signals of telecontrol and ten signals of requested telemetering. The transmission time of one order takes 2-1/4 seconds. For economy the communication channels of the UTB-55 system permit the connection to one

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channel of up to four controlled points (stations, substations) which are working from one common system of arrangement of telecontrol and telesignal on the dispatcher point. In this case, the number of manual signals of telecontrol and telesignals on all four stations should not exceed above indicated numbers.

In order to obtain higher speed it was necessary to select the signals by means of three consecutive timed steps and for an order four steps. For this purpose, all eighty signals are distributed in eight groups with ten signals in each group. The first six impulses select the number of the group and the seventh symbol checks by means of definite characteristics, the correctness of the selection, and the remaining impulses execute the selection of the ten signals of a given group.

The UTB-55 system is built according to a block principle which permits the assembly of individual blocks. The blocks are designed for twenty points of telesignals and nine points for telecontrol. The signal block for twenty points in the arrangement of telecontrol and telesignals at the dispatcher point consists of a selector of the SHI-11 type, twenty signal relays Type RKN and four general relays. The selection of the number of the group of signals is obtained by a selector of the Type SHI-17. The operation of the telecontrol is obtained by means of only one selector SHI-17.

The automatic starting of the arrangement at the controlled point and during the switching from one controlled point to another is made by means of a special starting scheme which consists of condensers and rectifiers. For a normal arrangement only one contact is required which is a considerable advantage of the UTB-55 system in comparison with other systems of supervisory control.

Blocks of individual signals and orders and also general operations are mounted on separate panels which are connected with other panels by means of connecting multi-channel plugs; this considerably helps the personnel to change

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the arrangement and also to remove damaged elements and to replace these elements with spare elements. This design also permits, in the future, to increase the capacity of this installation.

The high current (intermittent) relays which are required for supervisory control are also mounted in blocks on panels. The relays and remaining apparatus are located in the cabinets, the dimensions of which are 2090 x 800 x 550 MM. (Figure 5)

In each cabinet there is a panel with switches for feeding lines and connecting lines, the starting button and also control signal bulbs which permit the personnel to quickly determine any faults and to adjust the equipment.

The cables for outside connections (from the panel or console and control units) are brought into the cabinet from underneath and are connected to special clamps which are installed inside of the cabinet. In the cabinets located at the dispatcher's point, the connection of outside cables is made by means of hot soldering and at the control point by means of screw clamps. The cabinets are reliably sealed against penetration of dust and of the surrounding air.

The supervisory control UTB-55 has been developed by the All-Union Research Institute of Electrical Energy in cooperation with plant "Electropult" (Leningrad).

The supervisory control of the Type TNCH-56 belongs to the class of frequency systems which permits the arrangement of the supervisory control over any means of transmission including the high frequency channels of high voltage power transmission lines. In that case, the distance of reliable transmission is measured in hundreds and thousands of kilometers, that is the reason why such systems are called systems of long distance action.

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For this purpose special conversion methods are used for the conversion of the measured value into an auxiliary value which is convenient for transmission through the given communication channel. This value must be such that the distortion effect in the process of transmission through the channel should not reduce the accuracy of the measurement. At the receiving end this value (after reconversion) is used to determine the actual value which has been measured at the controlled point.

In arrangement TNCH-56 the measured value is converted into alternating current, the frequency of which changes in exact proportion with the variation of the measured value at the given moment of time. The working range of the frequencies which are transmitted to the channel is 44-27 cycles which corresponds to the limiting values (100 and 0 per cent) of the measured value. The latter is converted by means of an induction converter into direct current, which in a special scheme controls the regulating motor which rotates the movable plates of the condenser of a sine wave generator, the frequency of which will change in proportion with the measured value.

At the dispatcher point the received frequency is converted in a special circuit into direct current which is sent to an indicating apparatus graduated according to the measured parameters (Figure 6).

The measuring accuracy is plus or minus 2 to 2-1/2 per cent. The transmitter and receiver are made with electronic tubes which have long life and are supplied from standard stock.

At the exhibition stand is demonstrated an arrangement of the TNCH-56 which is designed for telemetering of total power of three components.

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Short Distance Supervisory Control Systems (Intensity Systems)

Such systems are designed to operate on separate independent lines (overhead or cable) and cannot be operated on multi-frequency channels. The operating distance depends on the quality of the line and is between ten and fifty kilometers. In these systems the current in the line does not exceed a few milliamps and the voltage a few volts.

The telemetering of power, water consumption, etc., is made by means of an induction-rectifying method.

For the measurement of power the movable system of the measuring apparatus is tied with the movable system of an induction converter. The latter converts the deflection angle of the instrument into a-c voltage, the magnitude of which is proportional to the deflection angle, i.e., to the magnitude of the measured power. The rectified voltage produces in the communication line a direct current (approximately one milliamp) which at the receiving end actuates the indicating instrument.

The accuracy of the measurement is approximately ± 2.5 per cent.

The telemetering of alternating current or voltage according to the rectifying method is obtained by rectifying the a-c or voltage outside of the measuring transformers. Direct current or voltage is transmitted to the dispatcher point where they actuate the indicating instruments.

On the exhibition stand a telemetering system for alternating current is shown. This system is built by the "Electropult" plant.

At the dispatcher's console a special indicating instrument of the Type PMDG-1 is used. This instrument is built by the "Electropult" plant. It gives a reading without parallax, because of the large radius of the pointer.

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Supervisory Control Without Contacts (Type BMT-58)

In the Type BMT-58 supervisory control a special discrete pickup is used (Type DI-2) Figure 7.

Contactless, long life elements are used in this system. The basic components are: impulse type magnetic elements with a rectangular hysteresis loop and magnetic amplifiers with a relaying action. Other static elements: germanium triods (in one line tie point), diodes, condensers, etc. are also widely used in this system.

Due to a complete absence of mechanical contacts and friction or moving parts, this arrangement is particularly reliable in operation and does not require a continuous attention and servicing for normal operation. These characteristics put the contactless arrangement into a higher quality group than all other arrangements.

The contactless arrangements become particularly important in a tropical climate, locations requiring explosion-proofness, large temperature variations, polluted air, presence of chemicals, outdoor operation, vibrations, mechanical shocks, etc.

The exhibited contactless supervisory control system belongs to the group of long distance systems and is designed for the operation with any method of communication (overhead and cable two conductor lines, subsonic and supersonic channels on communication lines and transmission lines, radio channels and radio-relay lines) and practically on any distance.

The operation of the BMT-58 system is based on the distribution method of selection.

The impulse distributors of the dispatcher and controlled points are brought to a synchronous motion by 50 cycle current impulses. The impulses are sent through the communication channel from the dispatcher point.

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The selection of the objects (points) of the supervisory control is made by means of time impulses by lengthening the intervals between the motion impulses. For the selection of a point, reversed impulses are sent through the channel during the intervals between motion impulses. Impulses are sent through the channel continuously; the BMT-58 arrangement of continuous operation thus differs from the usual supervisory controls of sporadic action.

The continuous transmission method provides a number of valuable properties: the system is considerably simplified due to the absence of complicated automatic starting circuits at the controlled and dispatcher points; the reliability of signal transmission is increased because it is repeated many times; the transmission speed is considerably increased; a reverse communication channel is not required, when telecontrol is not required; the transmission of discrete telemetering is simplified.

The exhibited arrangement is designed for ten two position signals, four controlled points and two calling points for telemetering. The time required to transmit a signal is: maximum 0.28 second, minimum 0.02 second.

For the discrete telemetering six steps are segregated in the impulse distributors.

The counting of the telemeter indications is made by means of a luminous digital display. The display lights are controlled by means of magnetic contactless relays.

In this system, the most important element is made from a magnetic alloy which has a rectangular hysteresis loop. (PPG)

The operation of this element is based on its ability to change abruptly the magnetic induction in the core from a positive value $+B_o$ to a negative value $-B_o$ as a function of the polarity and magnitude of the magnetizing impulses, or to maintain it practically constant. An impulse at the outlet of a

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PPG element will appear due to the action of feeder impulse only if the preceding control impulse creates a positive induction $+B_o$ in the core. The outlet impulses are used either for further amplifications, or as an indicator of the type of a previously supplied control impulse. In the latter case the PPG element becomes a "memory" and is used as a recording relay in the impulse distribution system.

The outlet elements of this arrangement are the contactless relays, i.e., the magnetic amplifiers which operate as relays (because they have a strong positive reverse connection).

The cores of all magnetic elements are made from a special magnetic alloy N50P.

The BMT-58 was built in the supervisory control laboratory and is a further development of the joint work of the Academy of Science, the ministry of power plants and the "Electropult" plant in the field of development of contactless supervisory control systems.

Discrete Telemetering (DT). The above described frequency and rectifier type systems require separate channels for the transmission of indications, which is the most expensive part of the entire supervisory control system.

The discrete telemetering (DT) does not require a separate channel and can operate over the same channels as other parts of the supervisory control. This gives it a high economic efficiency.

With the discrete telemetering, instead of transmitting a continuous row of measured values, only a limited number of these values is transmitted (as a percentage of the maximum value) these values are transmitted through the supervisory control system as ordinary telesignals. The contactless supervisory control on the console is used for this purpose.

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The exhibited pickup apparatus Type DT-2 transmits twenty whole values in the entire range of the measured parameter. The error is ± 5 per cent which is permissible, for example, for the measurement of feeder currents. For the measurement of voltages the error can be reduced 2 to 2.5 times by the method of suppression of zero. The simplicity of the construction of this apparatus DT-2 and also the simple method of coding of the transmitted values is a considerable advantage of this system in comparison with the standard methods.

The DT-2 apparatus is built as an ordinary electrical measuring apparatus. Along its scale are located twenty contact plates and the pointer carries on its end a contact fork. Since the apparatus is permanently subconnected to a measuring transformer or another pickup indicator, the position of the pointer always corresponds to the value of the measured parameter at the given time.

All twenty plates are subconnected to eight outlet circuits of the contactless distributor of the supervisory control arrangement. When the dispatcher calls a required parameter, the contact fork of the pickup will be pressed against one or two corresponding plates and a signal corresponding to the measured value will be transmitted to the communication channel. At the receiving end, the received signal, through its executive relay, will connect a calibrated resistance which will determine the magnitude of the current supplied to the indicating instrument.

The DT-2 apparatus was developed by the VNIIE Institute.

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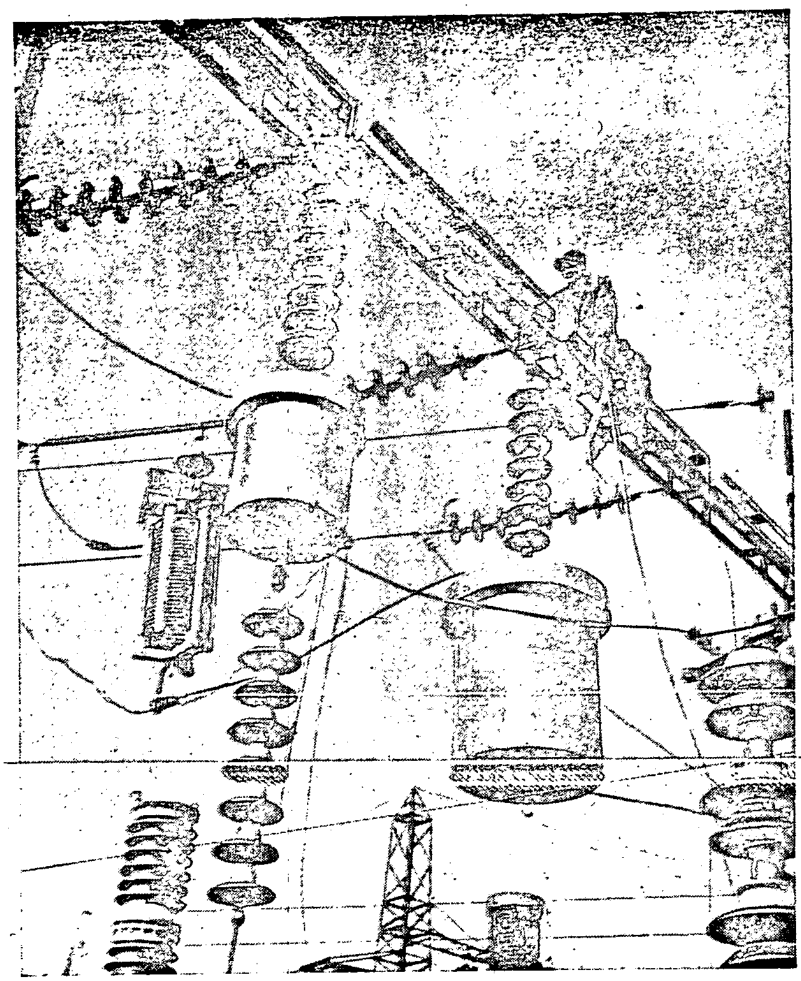

Рис. 2. Монтаж аппаратуры обработки высоковольтных линий электропередачи для организации высокочастотных каналов связи и телемеханики.

и всей энергосистемы, контроля загрузки трансформаторов, потоков энергии по линиям электропередачи, а также напряжения в различных точках высоковольтной сети и частоты в системе. Кроме того, на гидроэлектростанциях осуществляются замеры уровня воды в водохранилищах, а на тепловых электростанциях — давления и расхода пара.

При помощи телесигнализации осуществляется непрерывный контроль из диспетчерского пункта за положением выключателей мощности, за работой устройств релейной защиты на линиях и агрегатах, а также местной автоматикой. Телесигна-

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ее распространение и этим не допустить перебоев в электроснабжении.

Диспетчерские пункты (объединенные, центральные, районные) широко оснащаются новейшей техникой — телемеханикой.

Различные типы современной телемеханической аппаратуры позволяют диспетчеру управлять энергосистемой с высокой оперативной четкостью и облегчают его труд.

Диспетчерский пункт и все станции и подстанции соединены телефонной связью.

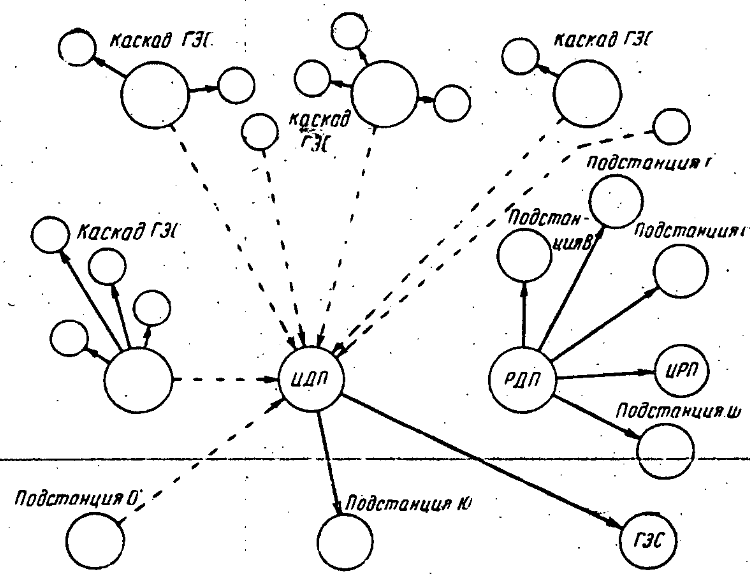

Рис. 1. Скелетная схема централизованного управления энергосистемой из единого диспетчерского пункта.

Телемеханическая аппаратура позволяет диспетчеру предельно централизовать управление сложным процессом выработки и распределения электроэнергии и осуществлять его наиболее эффективно с точки зрения народнохозяйственных интересов в целом.

Введение телемеханики сопровождается оснащением станций и подстанций местной автоматикой, что дает возможность значительно уменьшить на них численность обслуживающего персонала, а на ряде гидроэлектростанций и подстанций — обходиться без дежурного персонала.

В Советском Союзе плановая телемеханизация энергетических систем началась в послевоенный период.

Промышленное производство серийной аппаратуры телемеханики получило развитие лишь за последние 5—10 лет. Теле-

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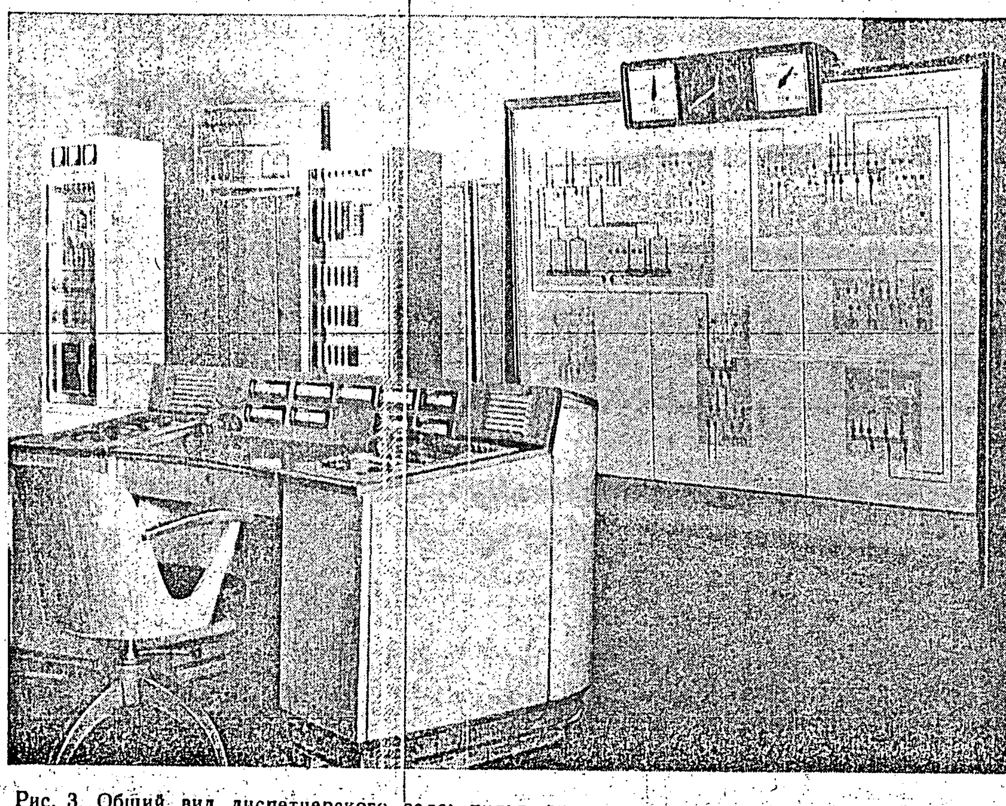

Рис. 3. Общий вид диспетчерского зала: пульт диспетчера, щит с мнемонической схемой энергосистемы, шкафы устройств телеуправления.

control

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Некоторые телеизмерения записываются на ленты самопишущими приборами.

Особо выделяется на диспетчерском пункте прибор — сумматор электрической мощности всей энергосистемы (рис. 3).

Устройство телеуправления-телесигнализации типа УТБ-55 построено по распределительно-временному принципу.

Передача сигнала или приказа заключается в посылке в канал связи серии следующих друг за другом импульсов электрического тока, разделенных интервалами. Номер сигнала (объекта) определяется номером импульса в серии. Позиция сигнала («включено» или «отключено») определяется удлинением соответствующего интервала. Число импульсов в серии — 17.

Прием более двух приказов свидетельствует о неправильной работе устройства. Передача сигналов также контролируется. В устройстве ТУ-ТС типа УТБ-55 обеспечивается высокая надежность исполнения операций ТУ и ТС (рис. 4).

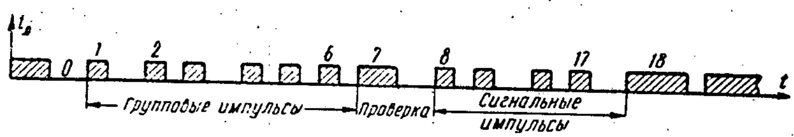

Рис. 4. Диаграмма импульсного кода устройства ТУ-ТС типа УТБ-55.

Принятая серия импульсов декодируется (расшифровывается) и выдает определенный исполнительный импульс: на диспетчерском пункте он включает сигнальную лампу, а на станции,— например, выключатель. Нормально устройство находится в покое и приходит в действие автоматически при переключении объекта.

Устройство УТБ-55 является сложной многофункциональной схемой, построенной в основном на электромагнитных реле телефонного типа и телефонных шаговых искателях. Напряжение питания — 60 *в* постоянного тока.

Устройство УТБ-55 рассчитано на 80 объектов ТС, 36 объектов ТУ и 10 объектов телеизмерения по вызову. Время передачи одного приказа составляет $2^1/_4$ *сек.* В целях экономии в каналах связи схема УТБ-55 позволяет включать в один канал до четырех контролируемых пунктов (станции, подстанции), работающих на один общий комплект устройства ТУ-ТС на диспетчерском пункте. В этом случае количество объектов ТУ и ТС на всех четырех пунктах в сумме не должно превышать указанных выше цифр.

Достижение повышенной скорости потребовало выбора сигнала тремя последовательными во времени ступенями, а приказа — четырьмя. С этой целью все 80 сигналов распределены

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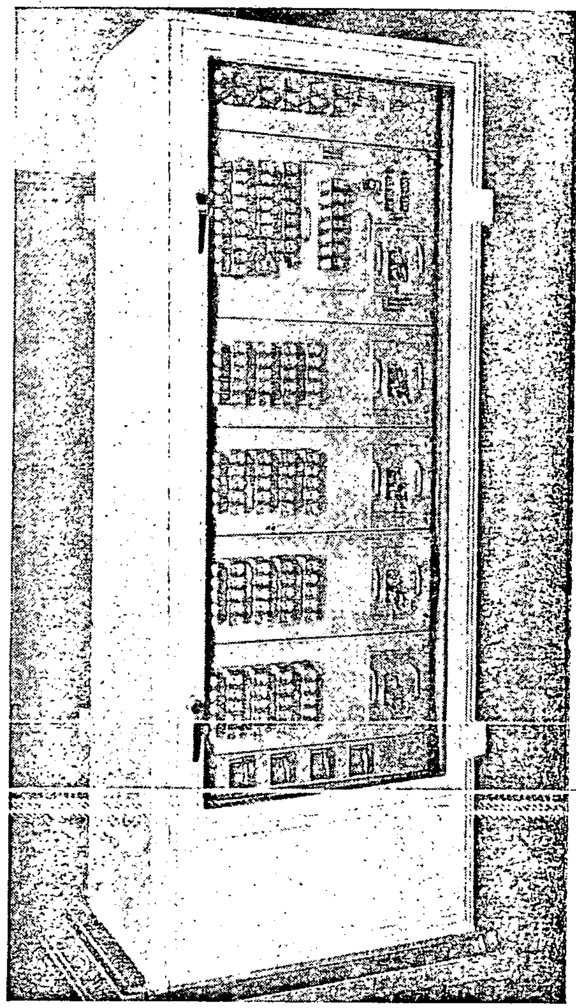

Рис. 5. Релейный шкаф устройства ТУ-ТС типа УТБ-55 (на диспетчерском пункте).

Устройство телеизмерения типа ТНЧ-56 относится к классу частотных систем, позволяющему осуществлять телеизмерительную передачу по любым видам связи, в том числе по высокочастотным каналам высоковольтных линий электропередачи. В этом случае дальность надежной передачи составляет сотни и тысячи километров, почему такие системы и называются системами дальнего действия.

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стоянный ток (порядка 1 *ма*), который на приемной стороне поступает в указывающий прибор.

Точность измерений составляет примерно $\pm 2{,}5\%$.

Телеизмерение переменного тока или напряжения по выпрямительному методу осуществляется путем выпрямления их за измерительными трансформаторами. В линию связи подаются постоянные токи или напряжение, которые на диспетчерском пункте непосредственно поступают в указывающие приборы.

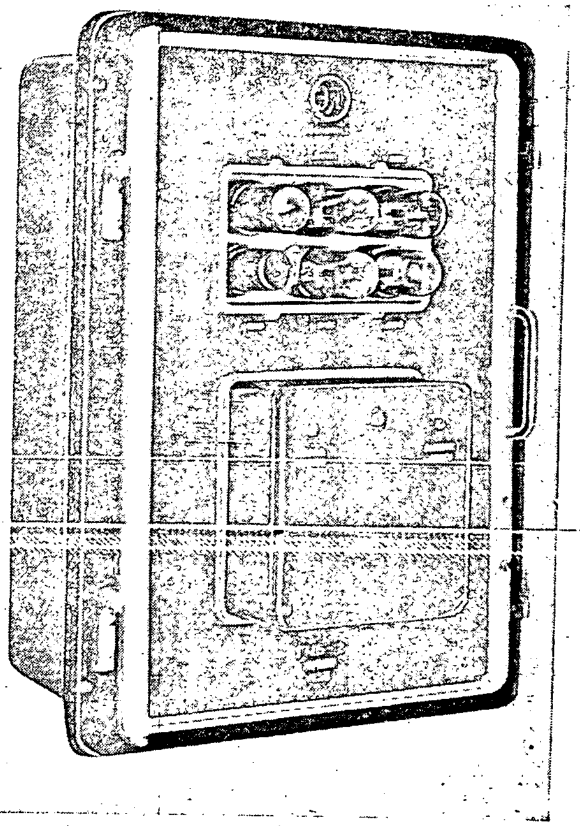

Рис. 6. Устройство телеизмерения типа ТНЧ-56 (внешний вид передатчика)

На стенде установлена система телеизмерения напряжения переменного тока, выпускаемая заводом «Электропульт».

Указывающим прибором на пульте диспетчера служит прибор типа ПМДГ-1 специальной конструкции завода «Электропульт». Он отличается беспараллаксным отсчетом благодаря большому радиусу стрелки.

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7. Телемеханическое бесконтактное устройство (тип БМТ-58).

Устройство типа БМТ-58 выполняет функции телеуправления, телесигнализации и телеизмерения (с помощью специального датчика дискретного телеизмерения типа ДИ-2) (рис. 7).

Устройство построено исключительно на бесконтактных долговечных элементах. Основными из них являются: импульсные магнитные элементы с прямоугольной петлей гистерезиса и магнитные усилители релейного действия; наряду с этим

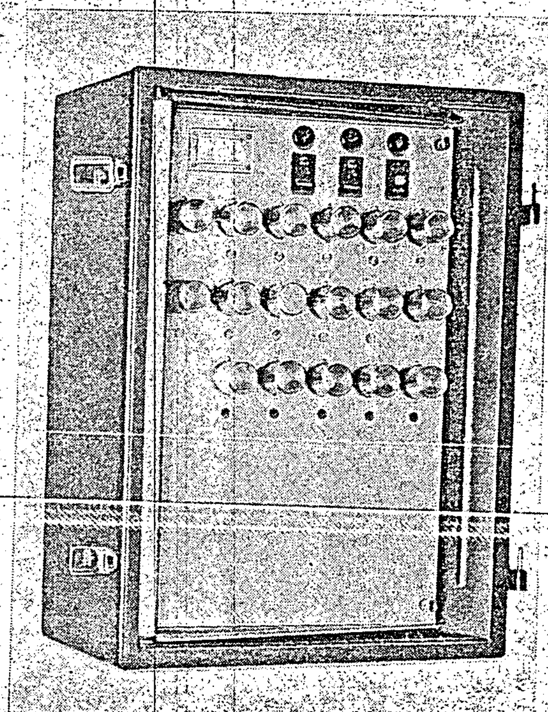

Рис. 7. Телемеханическое бесконтактное устройство типа БМТ-58 (внешний вид шкафа диспетчерского пункта).

в схеме широко используются другие статические элементы: германиевые триоды (в одном линейном узле), диоды, конденсаторы и т. п.

Ввиду полного отсутствия механических контактов и трущихся или подвижных частей устройство отличается исключительно высокой надежностью и безотказностью действия и не требует для своей нормальной эксплуатации постоянного обслуживания и ухода. Эти свойства делают бесконтактное устройство качественно отличным от всех известных типов.

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8. A System For The Regulation of Active Power For The Automatic Regulation of The Frequency and Load of Groups of Multi-Unit Power Plants.

The system for the regulation of active power (UKAM) is based on the direct utilization of the turbine speed regulators for the automatic control of the operation of a power plant. An accurate control of the frequency (according to the astatic characteristic) is obtained directly by the turbine speed controls of the power plant and the most efficient distribution of load between individual units is obtained. The output of the power plant is maintained or adjusted depending on the requirements and a given load distribution between units is maintained.

The UKAM consists of electromagnetic regulators which supplement the turbine speed controls and the power plant equipment for the measurement and control of power. 8

The electromagnetic regulator for the speed control of each turbine consists of a pick up of the opening of the guide apparatus DO (Fig. 1) and the power block (Fig. 2).

The pick up consists of an induction coil with a moving core, which is connected to the guiding apparatus of the turbine and thus ties the turbine controls with the inductive resistance of its coil.

The power block consists of electromagnets which are acting against each other and are actuating an armature, which is connected to a booster slide valve. The power block is the electric input element of the turbine speed control. The electromagnetic regulator converts the hydro-mechanical speed regulator into an electro-hydraulic regulator, which can operate not only as a function of the rpm of the units but also as a function of other parameters expressed by electrical values.

The electromagnetic regulators of all units in a power plant are interconnected and also connected to a central measuring and power control system of the plant into a single coordinating system. (Fig. 3).

Control systems for power plants consist of a static transformer (Fig. 4), which is used to measure the summary of the output of all turbines in the power plant, and power and frequency pick-ups, which are built in the form of rotary transformers (Fig. 5). The rotor of the transformer is controlled by an electric drive.

During the operation of any number of units in the power plant the frequency level is adjusted by the frequency pick-up and is maintained by the turbine speed controls, which are set for astatic operation.

When the power output of a plant must be maintained at a given level or when it varies because of load variations, the power pick-up is connected and the required changes are obtained by the rotating of the pick-up rotor by electric signals which originate either in the power plant or are received from outside.

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The UKAM system is installed in several (over 10) hydro-electric plants in the Soviet Union. Experience shows that such automation, at minimum cost, permits automatic frequency control with an accuracy not less than $\pm$ 0.1 cycle and power control with an accuracy of $\pm$ 3%.

A mass production of the UKAM equipment is made at the electric repair plant in Rostov.

ILLUSTRATIONS

Fig. 1 - Opening pick-up. UKAM
Fig. 2 - Power block UKAM.
Fig. 3 - UKAM coordination diagram.

DO - Opening pick-up
CB - Power block
CP - Distribution resistance
TC - Static transformer
C_{TC} - Capacity of the static transformer
3M - Power pick-up
DC - Static choke
K4 - Frequency regulator
D4 - Choke of the frequency regulator
Cy - Capacity in the equalizer circuit
KP_1 - Contact for power regulation
KP_2 - Contact for frequency regulation
YP - Equalizing conductor

Fig. 4 - Static transformer UKAM
Fig. 5 - Power pick-up UKAM

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9. ELECTRICAL RPM RELAY

The electrical rpm relay is designed to control the rpm of a power unit during the starting and stopping and also to energize the protective equipment in the case when the power unit overspeeds. The relay performs the following operations:

1. Connects the synchronizing circuits.
2. Connects the generator to the line.
3. Connects the brake during a shutdown.
4. Releases the brake after the shutdown.
5. Connects the protection from overspeed.

This relay was designed in 1957 using previous designs of rpm control equipment, which has been used in hydro-electric power plants. The relay is connected to the pendulum-generator of the water wheel generator and if the pendulum generator is not available it is connected to a special tachometer-generator. In comparison with a mechanical relay, the electrical relay is more reliable because it is tied electrically to the shaft of the generator and has no rotating or moving parts (except for the cores of the relay). The relay is designed for installation on an automatic control panel, which reduces the length of the connecting cables. 9

The schematic circuit of the relay (Fig. 1) consists of two parts:

I. The circuit for the control of braking, starting and overspeed control includes:

   a. Braking rpm pick-up DO-40
   b. Overspeed rpm pick-up DO-140
   c. Rectifier B_2
   d. Equalizing condenser C_3
   e. Thermal resistance TC
   f. Adjustable resistances R_1 and R_2

II. The circuit for the control of zero rpm, includes:

   a. Resonance circuit LC_1
   b. Rectifier B_1
   c. Zero rpm pick-up DO-0
   d. Time delay condenser C_2

The voltage and frequency which are supplied by the pendulum generator to the electric rpm relay vary with the rpm of the power unit. The voltage supplied to DO-40 and DO-140 is proportional to the voltage of the pendulum generator and the voltage supplied to DO-0 has a shape as shown by Curve 16 (Fig. 2) due to the effect of the resonant circuit LC_1.

The relay works as follows:

During the acceleration of the unit the zero rpm pick-up is pulled up and stays in that position when the unit is in operation. When the unit approaches

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the synchronous rpm the DO-40 pick-up operates and also remains in the pulled up position during the operation of the unit. During the shutdown of the unit the pick-up DO-40 drops down and fixes the braking rpm of the unit. The control of the sub-synchronous speed and the braking speed by the same relay is achieved by the proper selection of the return coefficient of the relay.

During the shutdown of the unit the condenser C_2 is charged and after the unit has gone through the resonant frequency of circuit LC, the condenser C_2 discharges through pick-up DO-O. The capacity of this condenser is selected so that the pick-up DO-O is released 15-20 minutes after a full shutdown of the unit. The pick-up DO-140 operates if the unit overspeeds. The thermal resistance TC is used for thermal compensation of resistance DO-140. It consists of an assembly of 16 mm. washers.

The rated voltage and frequency of the relay must correspond to the voltage and frequency of the pendulum generator and are specified by the customer.

The laboratory adjustment of the relay is made on a special stand, which consists of a three phase generator with an independent excitation. The generator is driven by a D.C. motor. By varying the rpm and excitation current of the generator within wide limits the ratio between the voltage and frequency are changed and as a result the parameters of all pendulum generators attached to water wheel generators can be imitated.

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10. DEVELOPMENT OF ELECTRIC TRANSMISSION LINES IN THE USSR

This booklet covers the construction and maintenance of transmission lines. Different types of supporting towers are given for A.C. and D.C. transmission lines. First wooden and steel towers are discussed, then reinforced concrete. In order to expedite the construction of lines the following methods have been adopted. Steel towers are prefabricated in sections which are bolted together in the field. The sections are zinc plated at the plant. Heavy towers have been replaced by lighter structures with guy-wires as shown in Fig. 9.

Reinforced concrete towers have also been used, however, with the rapid expansion of transmission lines steel and wood are considered preferable.

Methods of detecting leaks have been developed which cut down the maintenance cost. Lately the impulse method of detection of leaks has been used successfully.

Aluminum alloys have also been used for towers. Reinforced concrete foundations are often also prefabricated, which cut down the erection time. Imported insulators were used first, however, now insulators made in Russia are used. Lighter transmission line wires are used. They are made from steel and aluminum. 10

Illustrations show different types of towers.

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11. Air Circuit Breaker Type BB-500

The air circuit breakers BB-500 are designed for outdoor installation. The apparatus has ten chambers for the interruption of the electric arc. These chambers are connected in series. A special ohmic shunting resistance reduces overvoltages which occur during the disconnection of short circuits and no-load lines.

The operation of the circuit breaker is obtained by the energy and high electric characteristics of compressed air. The rated air pressure is 20 atm.

Basic Technical Data

Rated voltage	500,000 volts
Rated current	2,000 amps
Maximum disconnected power	20,000,000 KVA
Maximum disconnected short circuit current	23,100 amps
Interruption time of the breaker	0.06 sec.
Rated air pressure	20 atm.
Overall dimensions of one pole:	
length	9512 mm.
width	3965 mm.
height	11200 mm.

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12. Single-Phase Power Auto-Transformer, (Step-Up) Type ODTGA - 138000/220

Capacity 138000/100000/69000 KVA
No load voltage $242/\sqrt{3} \pm (2/2.5\%)\ (121/\sqrt{3})$ 13.8 KV.

Designed for the connection in a three phase group with a capacity of 414,000/300,000/207,000 KVA. Connection scheme and group Yo auto / Δ-11. This transformer is used for the connection of a generator to a 110 or 220 KV network. A combined operation is possible with the generator connected to a 220 KV line and simultaneously a 110 KV line connected to a 220 KV line.

The 242 KV winding consists of two concentric windings connected in series. The outer coil is designated as the series part and the inner coil, which is also the 121 KV winding is designated as the general part of the autotransformer winding. A current equal to the difference of the primary and secondary currents is flowing through the general part of the winding.

The losses are:

High - medium voltage	300 KW
High - low "	250 KW
Medium - low	303 KW
No-load losses	208 KW
Efficiency, referred to 100,000 KVA capacity	
High - medium voltage	99.45%

The core of the autotransformer is made of cold rolled steel. The steel is insulated by a film of varnish. 12

The 242 KV winding is equipped with a protective capacity against storm over-voltages. This capacity is provided in the form of screening turns on the high voltage inlet coils.

The autotransformer is oil cooled with forced draft.

Overall dimensions of the autotransformer:

Plan dimensions	9500 x 6300 mm.
Height	8700 mm.
Weight	
Removable part	76 ton
Tank with aux. equipment	46 ton
Oil	65 ton
Total Weight	187 ton

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13. Current Transformer Type TFNKD-500

This transformer has a porcelain tank. It is designed for outdoor installation. Cascade type. For differential protection.

Basic Data

Rated voltage 500 KV.
Rated primary current 500-1000-2000 amps.
Rated secondary current 1 amp.
Number of cores 4 (3 for relay protection and 1 for measuring apparatus).
Rated secondary loads: 30-50-75 VA.
Weight of transformers with oil 4.6 ton.
Height 5.46 m.
Base area 1.23 x 1.412 M.

These transformers are assigned for the high voltage transmission line between Stalingrad and Moskow.

Built By:

Zaporozsky Transformer Plant.

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14. Voltage Transformer Type NKF-110-57

Single-phase, cascade, three-winding, with natural oil cooling, for outdoor installation.

Rated transformation coefficient:

$$\frac{110{,}000}{\sqrt{3}} \Big/ \frac{100}{\sqrt{3}} \Big/ 100 \text{ volt}$$

This transformer is designed for networks with a grounded neutral; it is used for measuring electrical values, relay protection from ground faults, automation and signal-transmission.

Capacity of the transformer

In accuracy Class 1	500 VA
" " " 3	1000 VA

Overall dimensions:

Plan	860 x 735 mm.
Height	1820 mm.
Weight	640 kg.

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15. Three Phase, Three Winding Transformer

TDTGY 20,000/110

Rating 20000/20000/20000 KVA with no load voltage 110,000 $\pm$ /2/2.5%/38500 $\pm$ /2/2.5%/6,600 volt. Connection scheme and group -Yo/Y_0/Δ - 12 - 11.

Transformer losses are:

a) No load losses	55.8 kw
b) Short circuit losses	134.9 "
c) Total losses	190.7 "

The transformer core is made from electrical cold rolled steel 0.5 mm. thick with varnish coating. The yoke of the core is provided with many steps to improve the distribution of the magnetic flux and to reduce the losses.

The 110 KV winding is provided with a capacity protection against atmospheric overvoltages in the form of screening turns on the high voltage inlet coils.

Overall dimensions:

Plan dimensions	6100 x 4600 mm.
Height	5580 mm.
Weight of removable part	28.6 ton
Weight of tank with aux. equipment	16.9 ton
Weight of oil	18.6 ton
Total Weight	64.1 ton

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ABSTRACT

18. ~~19~~. DEVELOPMENT OF ELECTRICAL POWER IN THE U.S.S.R. IN 1959 - 1965 BY A. M. NEKRASOV

Table of Contents

Development of People's Economy and the Balance of Electric Power in U.S.S.R.

All along electric power has advanced faster than the development of industry. From 1913 to 1958 the overall production of the entire industry has increased 36 times and the manufacturing facilities have increased 83 times. During the same period the electric power generation has increased 120 times.

It is estimated that from 1958 to 1965 the overall production of industry will increase by 80% and in the same period the generation of electrical power will increase 2.1 - 2.2 times.

Table I gives the data for the growth of the basic branches of industry from 1958 to 1965 and 1972.

TABLE I

Type of Production	Units	Produced in 1958	Planned Level of Production for 1965	1972
Iron ore output	Millions of tons	88.8	150-160	250-300
Production of cast iron	Millions of tons	39.6	65-70	75-85
Production of steel	Millions of tons	54.9	86-91	100-120
Coal output	Millions of tons	496	600-612	650-750
Crude oil output	Millions of tons	113	230-240	350-400
Gas output	Billions of cub.m.	29.8	150	270-320
Cement output	Millions of tons	33.3	75-81	90-110
Generation of electrical power	Billions of KW hours	233.0	500-520	800-900

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Industry and construction works will be the main consumers of electrical power.

The production of nickel, magnesium and titanium will be increased. These will require a large amount of electrical power. In 1965 the production of electric furnace steel will increase two fold and the production of aluminum 2.8 - 3 fold.

The consumption of electric power by agriculture has increased and will increase even more in the following years.

The electrification of railroads is progressing rapidly. At the end of 1958, 9500 KM of railroads were electrified. By 1965 additional 20,000 KM will be electrified. The railroads between Moscow, Kuibishev, Irkutsk and the far East will be electrified, also Moscow, Gorky, Sverdlovsk. Moscow Kazan, Svedlovsk, Karaganda, Magnitogorsk, Ufa. Until now D.C. was used for Railroads. Now a 137 KM experimental line using A.C. has been built between Ozerelie and Pavletz. Out of 20,000 KM of Railroads which will be electrified, 11,000 KM will be electrified with A.C. which will cut the capital investment by 15-20% and will reduce the amount of copper required three times.

In 1965 the Railroads will require 40 billion KW hours.

Home appliances are also requiring more electric power. In 1956, 1957 and 1958 the following output was achieved: 10,798,000 radio receivers, 2,114,000 television sets, 865,000refrigerators. 2,000,000 KW are required for above appliances and another 2,000,000 KW for small appliances. By 1965 the consumption of electric power by home appliances will be doubled.

The generation of electric power in 1965 will be increased to 500-520 billions of KW hours against 233 billion KW hours generated in 1958.

Present Status and Development of Electric Power (general data)

The generation of electrical power in 1958 was 233 billion KW hours and the installed capacity of electric power plants 53.1 million KW.

80.5% was generated in steam power plants and 19.5% in hydroelectric plants. The increase in power generation during the last three years (1955-1958) was approximately 21.1 billion KW hours per year or 12.4% per year.

The increase of installed capacity and power generation in the Soviet Union from 1928 to 1958 is shown in Table 2.

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TABLE II

Year	All Power Plants: Capacity Thousand KW	All Power Plants: Generation of electric power millions of KW hours	Hydro-electric stat.: Capacity Thousand KW	Hydro-electric stat.: Generation of electric energy millions of KW hours	Per Capita Generation of electric power KW hrs.
1928	1905	5007	121	430	--
1932	4677	13540	504	812	--
1937	8235	36173	1044	4184	218
1940	11193	48309	1587	5113	--
1945	11124	43257	1252	4841	--
1950	19614	91226	3218	12691	474
1955	37296	170225	5986	23165	861
1956	43470	191653	8498	28984	958
1957	48396	209634	10040	39429	1027
1958	53100*	233000	10900*	45700	1162*

*Preliminary data

The trend is toward centralization i.e. construction of larger power plants. Estimated generation of electric power: in 1965 - 500 to 520 billion KW hours, in 1972 - 800 to 900 billion KW hours.

The installed capacity will increase in 1965 to 110 - 112 million KW or an additional 58 - 60 million KW of new power plants. The above increase will be divided as follows: 47-50 million KW new steam power plants and 10-11 million KW of hydroelectric power plants. The generation in steam power plants will be 85% and hydroelectric plants 15%. An average yearly increase of 12% is required.

In 1972 the installed capacity will be 180-200 million KW.

An increase of power capacity is planned in all republics of the Union:

in Russia - more than doubled
in White Russia - 2.6 times
in Azerbeidzan - 2 times
in Litwania - 2.9 times
in Estonia - 5 times

In Siberia and Kazakstan - 2.5 times.

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In order to expedite the construction of power plants, it has been decided to give priority to the construction of steam power plants in the next seven or eight years. These plans will be operated with low grade coal, natural gas and fuel oil.

In the same time, transmission lines will be built at high speed, which will permit the best utilization of electric power.

Fuel Balance and Utilization of Power Resources

The total geological deposits of coal, oil, gas, peat, wood according to 1937 estimates was 1433 billion tons. Power resources estimated in 1956 (hard fuel, oil, natural gas and water power) is 1950 billion ton of standard fuel. The Soviet Union has enormous water power capacity which is estimated at 1700 billion KW hours per year.

Most of the fuel deposits (about 80%) and other resources are located in Asia. However, most of the power consumption is in Europe.

In the last two years many power plants in Moscow, Harkov and Kiev have been changed to use natural gas as fuel.

In 1958 the fuel balance of the country was: 59% coal, 39% oil and gas, 10% other fuels; peat, wood, etc.

In 1965 the fuel balance is estimated to be: 43% coal, 51% oil and gas, and 6% other fuels.

In 1965 in Siberia and the far East, the output of coal (mostly strip mining) should be 75 million of tons per year. This will provide cheap fuel for the large steam power plants.

In the Ukraene the Lvov-Velyn coal basin will be developed.

In White Russia large oil refineries will be built as well as gas pipelines and new peat mines.

In the Uzbek Republic large gas deposits are available in Buchara.

Oil and gas will be used in power plants of the Georgian, Azerbeidzan and Armenian Republics. The use of gas and fuel oil in power plants cuts down the cost of installation per KW approximately by 20% and also reduces the capital investment for the pumping of gas in comparison with the mining of coal. The shipping cost is 1.5 to 2.5 times lower.

The use of gas, fuel oil and low grade Siberian coal will reduce the cost per KW hour of electrical power.

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Steam Power Plants

The first steam power plants which were built before 1930 had a total capacity up to 100,000 KW. Most of the turbines in these plants had a rating of 10,000 - 25,000 KW with steam pressure 13-16 absolute atm. (1910 - 2350 psi) and superheat temperature of 325 - 350°C(610 - 660°F).

The capacity of power plants and the rating of turbines has gradually increased and from 1946 power plants with a capacity of 300,000 KW and larger have been built.

The steam conditions in these power plants is 100 abs. atm. (1470 psi) and 500°C (932°F).

During the last decade power plants with higher steam pressures and temperatures were built.

In 1954 the Cherepets Power Plant was put into service with turbines rated at 150,000 KW each and steam boiler which generate 240 tons per hour of steam at 170 abs. atm. (2500 psi) and superheat temperature of 560°C (1040°F).

At the present time, 60 turbine-generators rated at 100,000 KW and five turbine-generators rated at 150,000 KW are in service. In 1958, 11 power plants were operating with a capacity of 500,000 to 750,000 KW each.

At the present time, most prime movers in power plants are steam or hydralic turbines which constitute about 87% of the total capacity. Power plants with diesel engines provide approximately 8%. All other plants have steam, gas and other engines.

Since the steam plants provide most of the power, their efficiency is particularly important and the reduction of fuel consumption is of prime importance.

Table 3 gives the specific fuel consumption per KW hour in district power plants.

TABLE III

	YEARS									
	1928	1932	1937	1940	1945	1950	1955	1956	1957	1958
Specific fuel Consumption For power Generation Grams per KW hour	820	761	624	597	576	542	480	470	457	442*

*Tentative

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The amount of fuel is given in grams as a basis for comparison.

The mechanization of fuel handling has been improved within the last ten years.

Within the last three years new construction methods have been adapted, which permit a faster construction of the plants and a reduction of the cost. In 1959 - 1965 most of the new power plants will be steam plants using coal, oil and natural gas. These plants can be built faster and at a lower cost.

The new power plants will be equipped with turbine-generators rated at 100,000, 150,000, 200,000, and 300,000 KW with boilers producing 420, 500, 640 and 925 tons of steam per hour. By 1965 it is planned to install more than 150 of such turbine-generators in expanded and new power plants.

Larger turbine-generator units are built. A 200,000 KW turbine-generator is being erected at the present time with a direct flow steam generator which will produce 640 tons per hour of steam. Turbines rated at 300,000 KW and 400,000 KW are in the design stage and corresponding boilers. In the manufacturing of these units, perlite steels are used which are cheaper than the austenitic steels.

In large steam power plants the most efficient technological scheme is used: a block consisting of a boiler-turbine-generator-transformer, which permits the utilization of the intermediate steam superheat. With such scheme, the connection of the boiler with the turbine is simplified, the length of steam piping is reduced and the number of shut-off valves can be reduced.

The new equipment for power plants will be more economical and will reduce the consumption of fuel per KW hour.

The increase of efficiency for turbine-generators rated at 100,000, 150,000 and 200,000 KW is obtained by using steam at 135 atm. (2,000 psi) pressure and superheat temperature of 565°C (1050°F).

The increase of the steam pressure and temperature and also the improved design of turbines permits to reduce the fuel consumption per KW hour output by 12-13% in comparison with units which operate at 1470 psi pressure and 932°F temperature. For turbines rated 300,000 KW the steam pressure is raised to 240 atm. (3530 psi) and 580°C (1076°F) which provides a fuel saving of 6-7%.

The increase of efficiency of the turbines is obtained by increasing the pressure and temperature of steam.

The intermediate single superheating of steam provides an additional 4% saving of heat.

The improvement of the design of direct flow section of the turbine i.e. the elimination of the double-crown(?) speed regulating wheel, the increase

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of the number of stages, the increase of the exhaust area for the condensation-type turbine which is compensated by the increase of length of the working blade of the last row and the use of multiple exhaust, increases the efficiency of the turbine by 2.5-4%.

The improvement of the component design of the through-flow section of the turbine such as: a more efficient shape of the stationary (guide) and rotating (working) blades, the reduction of the clearance between the blade tips and the cylinder of the turbine and other improvements gives an efficiency increase of 1.5-2.5%. The increase of the nonregulating extraction points of the turbine for regeneration increases the efficiency by 0.5-0.8%.

A number of improvements are made to improve the efficiency of the boilers such as: reduction of the temperature of exhaust gases, etc.

The coal handling equipment is improved by providing bunkers which hold a 24-hour supply of coal. The feed water is chemically checked.

The buildings of steam power plant are usually assembled from prefabricated reinforced concrete sections, which reduces the erection time. In some sections of the country where climate permits, semi-outdoor and outdoor power plants are built. The cost of such plants is lower and the erection time is reduced by four to six months.

The automation of controls and the use of gas for fuel will increase the reliability and reduce the installation cost by 20 to 22%.

Table 4 gives the cost (in rubles) of an installed KW of power in large power plants.

TABLE IV

Rating of Power Plant 1000 KW	Number and rating of turbines	STEAM CONDITIONS: 90 atm.535°C hard fuel	90 atm.535°C gas or liquid fuel	130atm.565/565° hard fuel	130atm.565/565° gas or liquid fuel	240atm.580/565° hard fuel	240atm.580/565° gas or liquid fuel
200	4x50	1265	895	--	--	--	--
400	4x100	1130	815	1105	795	--	--
600	4x150	--	--	945	695	--	--
1200	8x150	--	--	885	650	--	--
800	4x200	--	--	890	675	--	--
1200	6x200	--	--	850	650	--	--
1200	4x300	--	--	--	--	805	625
1800	6x300	--	--	--	--	765	600
2400	8x300	--	--	--	--	740	580
1800	3x600	--	--	--	--	655	520
2400	4x600	--	--	--	--	620	495

Note: To convert 1 atm. into 1 psi multiply by 14.7
To convert °C into °F use formula °F = 9/5 °C + 32

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Even larger power plants (up to 2,400,000 KW) are designed with turbo-generators rated at 600,000 KW each. The efficiency of such plants will be higher.

During the next seven-year period a boiler turbine unit rated at 300,000 KW will be installed. This unit is designed to operate at supercritical pressure of 300 atm. (4410 psi) and 650°C (1200°F), which will increase the efficiency of the unit by 21-22% in comparison with units operating with steam at 90 atm. and 500°C. The construction of this unit will require expensive austenitic steels. Therefore, the feasibility of wide use of such units will be decided after operation experience is obtained from the first unit.

In the next seven-year period gas turbines rated at 25,000 to 50,000 KW will be installed. About ten power plants are planned with rated capacity from 50,000 to 200,000 KW with gas turbines.

These plants will be constructed in regions where there is a shortage of water and in regions located close to gas pipelines or oil producing regions.

The efficiency of gas turbines which are scheduled for 1960 by the Leningrad metal plant will be 29% for a 25,000 KW turbine, and 33.5% for a 50,000 KW turbine designed by the Kharkov turbine plant.

Heat Generation

In large cities Leningrad and Moscow exhaust steam from power plants is used for industrial purposes and heating of buildings.

A considerable increase of heat generating plants is planned.

Hydroelectric Power

The construction of hydroelectric power plants provides low cost electric power. It also improves the navigation of rivers, provides irrigation of dry land, drainage of swamps, and improves the health conditions of the region.

The Volga-Kama cascade, consisting of 13 proposed hydro-power plants: six are in operation and two are under construction.

As a part of this cascade the largest Volga Plant named for Lenin, rated 2,300,000 KW was put in operation in 1957 and in 1958 this plant generated ten billion KW hours. At the Stalingrad Plant with a design capacity of 2,530,000 KW the first three units were installed in 1958.

On the Dniepr cascade, which will consist of six plants, two plants are in operation and two under construction.

Cascades are completed on the Kolsk peninsula, in Georgia, Uzbekistan, etc.

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In the last years the development of Siberian rivers has started. The Ust-Kamenogorsk Plant on the Irtysh, and the Irkutsk on Angara are completed and are in service. The Novosibirsk Plant on the Ob River is being completed and the Bukhtarminsk Plant on the Irtysh is under construction.

The construction of the largest hydroelectric plants in the world has been started: the Bratsk Plant on the Angara River and the Krasnoyarsk Plant on the Yenisey River.

At the end of 1958 the installed hydroelectric power was 11 million KW.

Automation and supervisory control have found a wide application in hydro-electric plants.

Comrad Krushev stated in his opening speech at the Volga Dam named for Lenin, that priority should be given to the construction of steam plants because of their lower cost and shorter construction time required.

During the period of 1959-1965 the following hydroelectric plants are scheduled for completion: Stalingrad 2,530,000 KW, Bratsk 3,600,000 KW, Kremenchug 625,000 KW, Vatkinsk 1,000,000 KW, Bachtarminsk 525,000 and a number of other plants. The construction of the largest plant will be progressing at Krasnoyarsk rated capacity 4,200,000 KW.

Atomic Power Plants

The Soviet Union is the first country in the world, where in 1954 was put in operation the first in the world Atomic Power Plant rated at 5000 KW. The operating experience of this power plant showed its high reliability of all components, the simplicity and convenience of operation. The system of biological shielding and special controls provide complete safety during the operation of the station for the operators and for the population located near the plant.

On the basis of the data obtained from the first plant, larger industrial atomic plants are designed. Most of the new atomic power plants which are under construction or in the design stage use water as a moderator.

In an atomic power plant which is being built on the Ural and is rated at 400,000 KW the steam is generated in the reactor vessel. At this plant, four reactors will be installed each connected to a turbine rated at 100,000 KW. The steam will be supplied to the turbines from the reactors at a pressure of 90 atm. (1323 psi) and a temperature of 480-500°C (900-930°F). At the present time, tests are completed on the boiling and superheating of steam and also the starting and shut-down methods for the reactor.

In the Voronezh district a 420,000 KW atomic power plant is built in which two water moderated reactors will be installed. In these reactors the heat is carried by water at 100 atm. (1470 psi) pressure. This water is circulated through steam generators and provides saturated steam at 29 atm. (426 psi) pressure which operates the turbine.

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It is assumed that in the future reactors of the latter type will be used. This eliminates the intermediate steam generators in auxiliary equipment.

At the present time, a boiling water reactor rated at 50,000 KW is under construction. An experimental investigation of sodium moderated reactors will be made on a 50,000 KW reactor. The reactor is designed to generate steam at 90 atm. (1325 psi) and 500°C (932°F). The maximum pressure of the moderator in the active zone will not exceed 8 atm. (118 psi) which is a great advantage in comparison with the water moderated reactors.

A fast neutron reactor rated at 50,000 KW is under construction.

When the above atomic plants are completed, the operating experience will permit the selection of the most efficient and suitable reactors for industrial use.

Power Systems and Power Transmission Lines

In this chapter the advantages of centralization are discussed. Construction of large power plants interconnected by high voltage transmission lines is also discussed.

It is proposed to connect the Central, Ural and Southern Districts by transmission lines at 400-500 KV.

Automatic control is widely used in many power systems.

Supervisory control is introduced all over the country.

Table 5 gives the length and voltage of transmission lines. D.C. transmission lines are used where large amount of power is transmitted on long distances.

Table 6 gives the construction cost of transmission lines in rubles per kilometer.

Capital Investment in Power Generation and Construction of Power Plants and Networks

Within the next seven years the capital investment in the construction of power plants and electric and thermal lines is established at 125-129 billion rubles which is a 1.7 increase in comparison with the period of 1952-1958 (in comparative cost).

In the next seven years the emphasis will be on the construction of steam power plants because of the saving in cost and construction time. The construction of steam power plants will be expedited by the use of prefabricated reinforced concrete sections for the buildings and the shipping of assembled units (boilers, turbines, etc.) which will reduce the erection time.

The construction of pipelines, gas and air lines will be expedited by the use of movable shops such as boiler shops, electric substations, compressors and also concrete plants, storage space, machine shops, etc.

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